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ABSTRACT

This study can be used in a geographic research methods course to show how nearest-neighbor analysis and regression analysis can be used to study various aspects of land use. An analysis of the sand, gravel, and crushed stone industry in three urban areas of Pennsylvania, Massachusetts, and Florida illustrates the locational problems faced by mining operations. Demand for sand, gravel, and crushed stone is about seven times the combined demand for the rest of the nonfuel nonmetallic minerals. Most mines producing sand, gravel, and stone are located in or near urban areas. There has been increased concern over the size of the operations, prices, the environmental impact of mining, the allocation of land for mineral extraction, social conflicts, and regulations and constraints affecting land use by the mineral aggregate industry. The creation of mineral resource zones by local governing bodies may be a means for reducing future conflicts and may provide the greatest potential for preserving sites for extraction of mineral aggregates. (RM)

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MINING MINERAL AGGREGATES IN URBAN AREAS

Robert D. Thomson

The role of mineral aggregates in our local, state, and national economies and the importance of the mining industry as the provider of these materials is generally poorly understood. Although mineral aggregates are fairly common in the earth's crust, they are not ubiquitous and, as is true of all minerals, they are non-replenishable, fixed point resources.

The importance of mineral aggregates in the United States can be illustrated by the quantitative demand for sand, gravel, and crushed stone, which is about seven times the combined demand for the rest of the nonfuel nonmetallic minerals. Sand and gravel and crushed stone, from a total raw materials usage, each account for about 20 percent of the weight of new basic raw materials used per person in the United States annually.

Most mines producing sand, gravel and stone are located in or near urbanized areas. The traditional economic decision to mine local material to avoid high transportation costs is being increasingly challenged. There has been increased concern over the problems of adequate mineral aggregate supply, environmental impact of mining, and the allocation of land for mineral extraction.

Analysis of the sand, gravel, and crushed stone industry in three urban areas has been made to illustrate the locational problems of today and the future.

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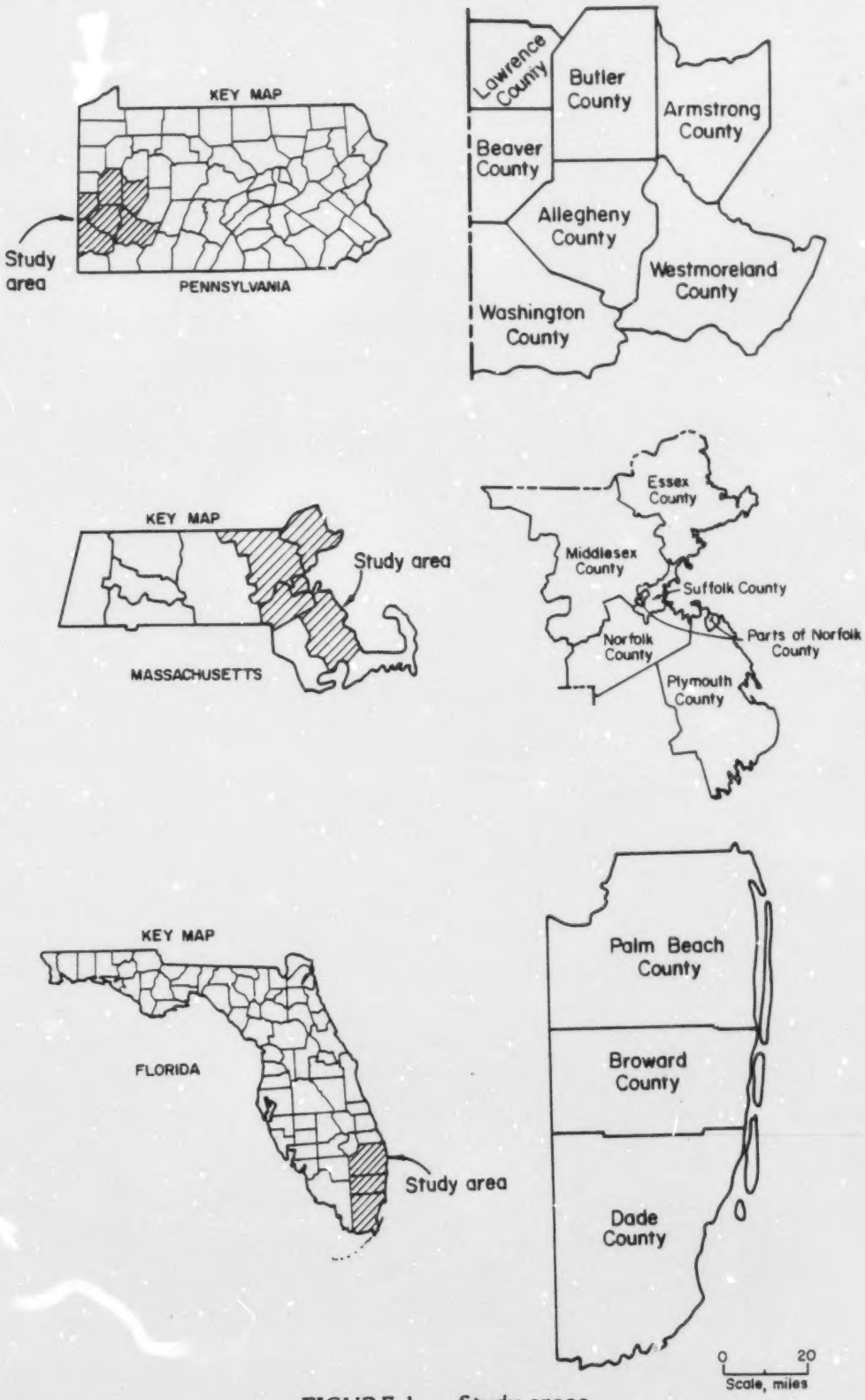

FIGURE 1. - Study areas.

MINERAL AGGREGATES INDUSTRY

Companies and Operating Sites

Mineral aggregates are produced from both surface mines and underground mines in Area 1 in Pennsylvania (table 1). The surface operations extract both sand and gravel and stone. The underground mines produce only stone. Sand and gravel is excavated from landlocked deposits, man-made lakes and river channels.

Sand and gravel for construction purposes is excavated from 17 bank-type deposits, two in Butler County, three each in Armstrong and Beaver Counties, and nine in Lawrence County. Material is excavated, processed and marketed from man-made lakes using dredges at one location each in Beaver and Lawrence Counties. River material is extracted from the Allegheny River at three sites in Armstrong County and one site in Westmoreland County and from one site in Beaver County in the Ohio River.

Sand and gravel is excavated from dry pits on land by a total of 18 companies, from man-made lakes by two companies, and from the Allegheny and Ohio Rivers by three companies. However, the total number of companies operating in Area 1 is 18 rather than the sum of these three groups. The difference is caused by certain companies operating pits in more than one county, operating both pits and dredges, or river dredges in two counties. One company operates a pit in both Butler and Lawrence Counties. Two companies mine sand and gravel from a pit and by a dredge on the river, while another company operates dredges and a pit operation in Armstrong County and a dredge in Westmoreland County.

Stone is mined, processed, and marketed as aggregate from mines in Allegheny, Armstrong, Butler, Lawrence, and Westmoreland Counties. Open pits

TABLE 1

Number of Companies and Type of Operations by Area and Counties

Area and County	Companies		Sand and Gravel				Stone	
	Sand and gravel	Stone	Dry pit on land	Wet pit on land	River bed	Bay	Pit	Underground mine
Area 1:								
Allegheny.....	-	1	-	-	-	-	1	-
Armstrong.....	3	4	3	-	3	-	3	2
Beaver.....	4	-	3	1	1	-	-	-
Butler.....	2	3	2	-	-	-	3	1
Lawrence.....	10	3	9	1	-	-	3	-
Westmoreland....	1	8	-	-	1	-	8	1
	1/ 18	19	17	2	5	-	18	4
Area 2:								
Essex.....	15	4	16	-	-	-	4	-
Middlesex.....	31	7	33	1	-	-	7	-
Norfolk.....	15	7	16	-	-	-	8	-
Plymouth.....	12	2	13	-	-	-	2	-
Suffolk.....	-	1	-	-	-	-	1	-
	73	1/ 19	78	1	-	-	22	-
Area 3:								
Broward.....	4	14	-	4	-	-	17	-
Dade.....	3	15	-	2	-	1	21	-
	1/ 5	1/ 28	-	6	-	1	38	-

1/ Number of companies may not add to number shown because some companies operated mines in more than one county.

or quarries are operating in each of the five counties by 15 companies. Three companies operate two quarries each in Armstrong, Butler, and Westmoreland Counties. The remaining 12 companies mine stone from a single site. Stone is produced from four underground mines by four companies, one each in Butler and Westmoreland Counties and two in Armstrong. Unlike the sand and gravel industry, stone producers only mine from sites within a single county.

Sand, gravel, and crushed stone are mined and marketed from each of five counties in Area 2 in Massachusetts. All three types of aggregate are mined in Essex, Middlesex, Norfolk and Plymouth Counties. However, only stone is mined in Suffolk County.

Sand and gravel is excavated from 79 deposits by 73 companies. The largest number of deposits (34) are mined in Middlesex County. Essex County and Norfolk County rank second with 16 mines each, followed by Plymouth with 13 mines. All the operations excavated material from dry pits on land except for one that excavates and processes sand and gravel from a man-made lake. Unlike Area 1, no sand and gravel is produced from river channels. Six companies operated from more than one pit within a single county. Three companies in Middlesex County operated two pits each, and one company each in Essex, Norfolk, and Plymouth Counties operated from two deposits.

Stone is mined, processed and marketed from open pits (quarries) in each of five counties. Seven companies in Middlesex and Norfolk Counties produced stone from seven and eight surface mines, respectively. The remaining seven mines are located in Essex, Plymouth, and Suffolk Counties and operated by six different companies. The total number of companies producing stone is 19 rather than the sum obtained by adding the number of companies for each county. The differences comes from one company operating a mine each in

Middlesex and Essex Counties, and another company having a mine in both Norfolk and Plymouth Counties.

Sand and gravel are excavated from bank-type deposits by town highway departments in each county except for Suffolk County. The tonnage produced each year by these noncommercial operations is small and is used mainly as fill material.

Sand and crushed stone for construction purposes is mined in Area 3 in Florida by commercial firms in Broward and Dade Counties.

Sand in Broward County is mined by four companies with each company operating a single pit. In Dade County, sand is produced by two companies from wet pits on land while one company extracts sand off the coast of Cape Florida in the bay using a suction dredge. Two companies have operations in both counties, bringing the total number of companies mining sand to five.

Crushed stone for construction purposes is mined by 14 companies from 17 deposits in Broward County and by 15 companies from 21 deposits in Dade County. Twelve of the companies in Broward County mined from a single deposit while one company operated three mines and another company operated two. In Dade County, twelve companies produced crushed rock from a single mine each; one company operated two mines; one company, three; and one company, four. One company mined stone in both counties. One of the companies mining stone also operated sand pits in both Broward and Dade Counties.

Commercial firms do not mine sand and stone in Palm Beach County. However, the Palm Beach City Highway Department does produce aggregate material for use in city projects from deposits within the county.

Distribution

Spatial patterns for sand and gravel and stone operations are shown in figures 2 through 4 for each of the three areas. A visual examination of these illustrations suggests a number of "loose" clusters and random patterns.

In addition to showing the spatial distribution of mineral aggregate producers using maps, a method of analysis that distinguishes between dispersed and clustered distribution is the nearest-neighbor analysis. The method quantitatively uses an index which indicates the degree of departure of an observed spatial distribution from a theoretical distribution. The index ranges from 0 (all points are closely clustered), to 1 (random distribution), to 2.15 (even distribution) (Hammond and McCullagh, 1974, p. 238). The index for each county and Area was calculated by dividing the measured mean-distance between nearest neighbor points and an expected mean distance of point randomly distributed in each area ($R = D_{obs}/D_{ran}$).

The pattern for sand and gravel and crushed stone mines in Area 1 approaches a randomness with a nearest-neighbor index of .893 (table 2). However, if individual counties are viewed the patterns vary. Operations in Lawrence County have a random pattern as shown in figure 2, with an index of 1.068. While operations in Westmoreland County are more widely distributed as indicated by an index of 1.541. Operations in Butler County are clustered in the northwest corner of the county and those in Beaver are clustered in the west central portion of the county. The index of .400 for Beaver and .487 for Butler mathematically confirms this pattern. Operations in Armstrong County approach a random distribution, with an index of .782. However, two clusters, one in the southwest and northcentral, do exist.

The distribution for Area 2 is somewhat a random pattern with an index of .742. Operations in Essex, Middlesex, and Plymouth show a random pattern

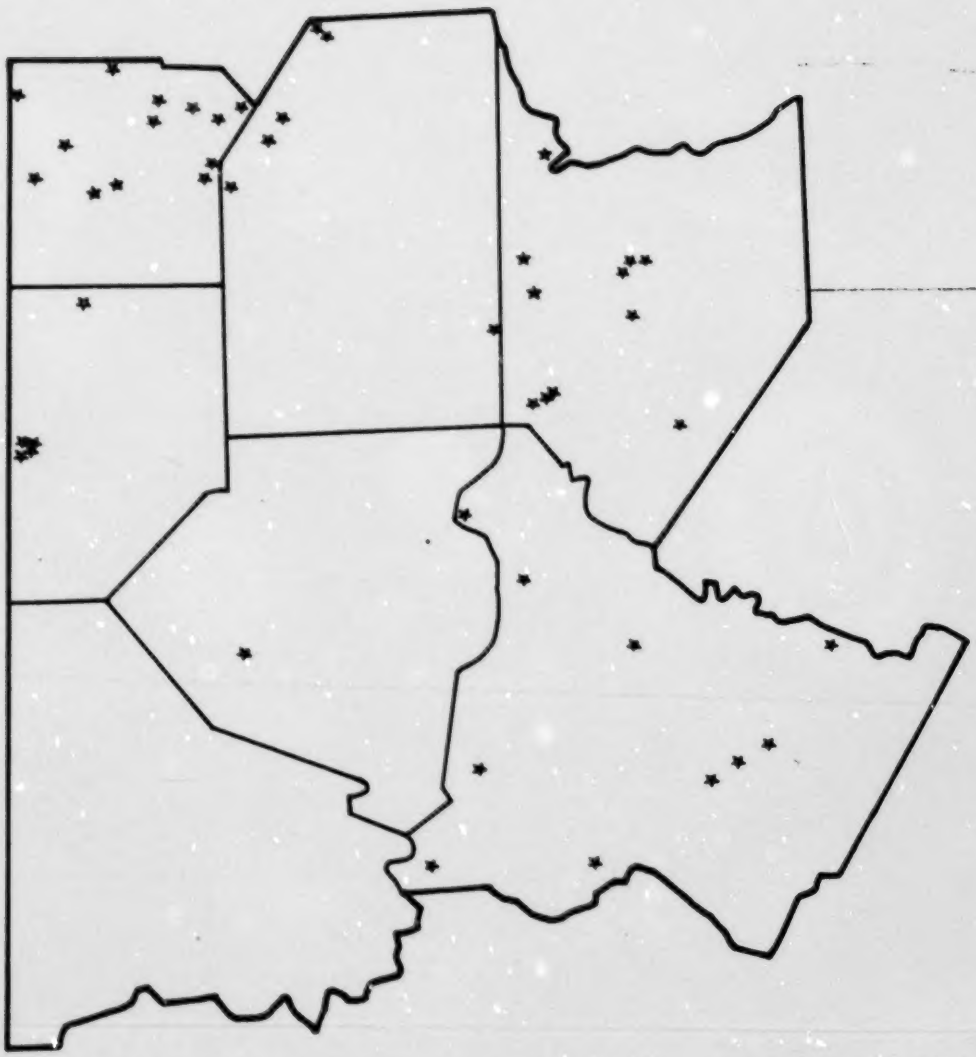

FIGURE 2. - Mineral aggregate sites in Area 1.

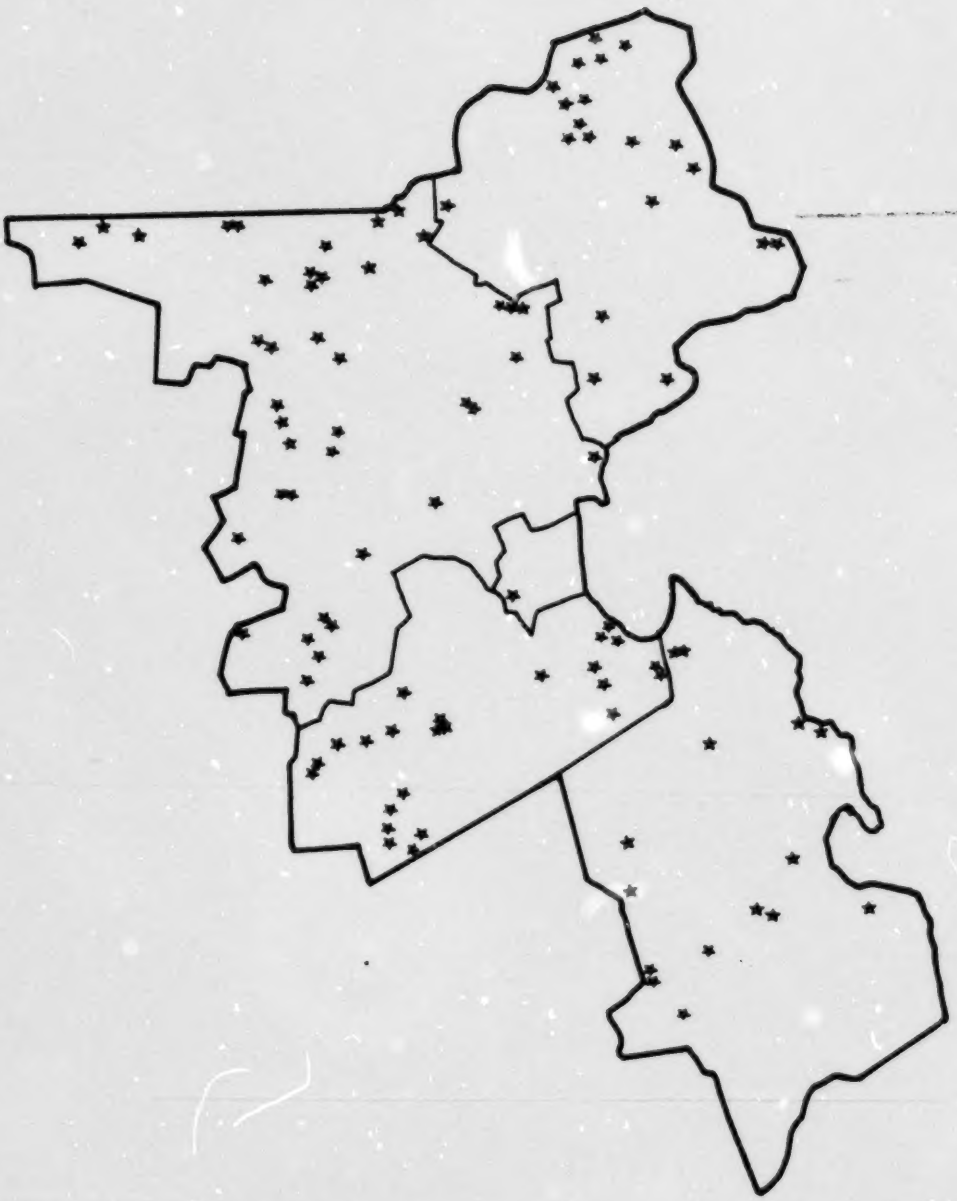

FIGURE 3. - Mineral aggregate sites in Area 2.

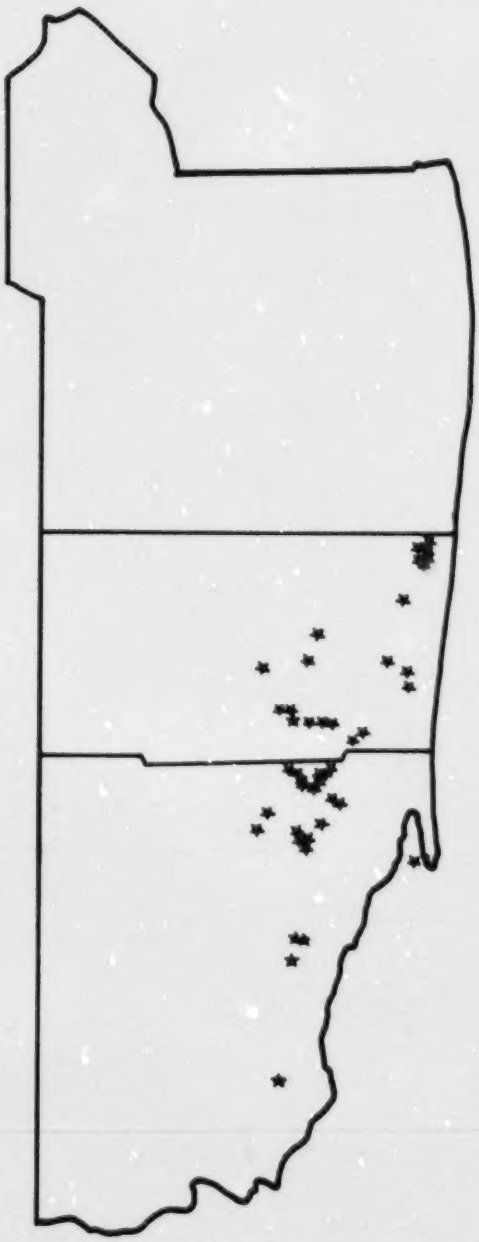

FIGURE 4. - Mineral aggregate sites in Area 3.

with indices ranging from a low of .699 to a high of .804. The mines in Middlesex show two random patterns - one extending southwest-northeast in the eastern part of the county and the other lying north-south in the western part. Several operations are located along a line near the west-north boundary. Operations in Plymouth County have a predominate random pattern across the central part of the county, lying in a southwest-northeast direction. The remaining mines are distributed randomly in the northern part of Plymouth County. Operations in Essex County are located in three clusters - one in the southern part of the county, another in the east-central part and the other in the northern part. However, the overall pattern in Essex County is random with an index of .699.

Mines in Norfolk County are located principally in four clusters. These clusters are in the eastern part of the county; central; south central; and west central. The index of .537 supports this observation.

The pattern for Area 3 appears as a clustering with a nearest-neighbor index of .467 (table 2). The indices for both Broward and Dade Counties also indicate clustering with values of .474 and .466, respectively. The mines in Dade are clustered principally in the northeastern corner of the county. Operations in Broward County are clustered in the southeast, east/central, and northeast parts of the county.

Size of Operations

The size of individual firms range from small independent producers with a single mine to large diversified corporations with multiple mine and plant operations, as well as other important commercial interests. Producers may sell aggregate for a single end-use or market a range of products. For two recent years, the number of operations for sand and gravel and stone by tonnage capacity classes in percent of operations and percent of total output are shown for each area in table 3.

TABLE 2

Nearest Neighbor Indices for Mineral Aggregate Operations

	Nearest neighbor index	Z Score
Area 1	.893	1.388
Allegheny	1.629	1.700
Armstrong	.782	-1.382
Beaver	.400	-2.566
Butler	.487	-2.989
Lawrence	1.068	.472
Westmoreland	1.541	3.273
Area 2	.742	-4.937
Essex	.699	-2.578
Middlesex	.804	-2.396
Norfolk	.537	-4.249
Suffolk	1.943	-1.803
Plymouth	.798	-1.562
Area 3	.467	-6.767
Broward	.474	-4.614
Dade	.466	-4.899

Sand and Gravel

The greatest portion of Area 1 sand and gravel operations in year one were in the 25,000 to 99,999 tons class (30 percent) and the 200,000 to 499,999 tons class (24 percent). However, the 200,000 to 499,999 tons class produced the major portion of the area's output (44 percent), followed by the 500,000 to 999,999 tons class (36 percent). A shift occurred in the second year with a higher percentage of the production falling in the 500,000 to 999,999 tons class and 5 percent of the operations reporting 1,000,000 tons or more output. Again, as would be expected, the major portion of the area's production came from the three largest classes, accounting for 86 percent of the production.

Most of Area 2 sand and gravel operations were in the less than 25,000 tons class, 25,000 to 99,999 tons class and 100,000 to 199,999 tons class. These three classes (80 percent of the operations) accounted for 45 percent of the area's output. The 200,000 to 499,999 tons class alone accounted for 40 percent of the tonnage in year one. In the second year, most of the operations still were in these three lower tonnage classes. The biggest change was that no producers were recorded in the 500,000 to 999,999 tons class with the two firms falling back to the next two lower levels.

More Area 3 producers reported sand and gravel output in the 200,000 to 499,999 tons class than any other tonnage class in year one. However, in year two, two operations increased their annual production and one each moved into the next higher tonnage classes. In both years more than half of the annual production came from operations in the 1,000,000 tons and over category.

TABLE 3

Number and Production of Operations by Area and Size
(percent of total)

Annual Production	Area 1				Area 2				Area 3			
	Operations		Tonnage		Operations		Tonnage		Operations		Tonnage	
	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
Sand and gravel:												
Less than 25,000....	21	18	1	1	25	24	2	2				
25,000 to 99,999....	30	27	9	6	28	24	14	11	28	38	6	7
100,000 to 199,999...	17	14	10	7	27	33	29	36	14	25	4	8
200,000 to 499,999...	24	18	44	21	17	19	40	51	44	13	36	10
500,000 to 999,999...	8	19	36	45	3		15			13		21
1,000,000 and over...		5		20					14	13	54	54
Total[1/].....	100	100	100	100	100	100	100	100	100	100	100	100
Stone:												
Less than 25,000....	27	11	2	1	12	6	1	1	7	6	[2/]	[2/]
25,000 to 99,999....	33	43	9	10	12	18	4	6	18	30	2	3
100,000 to 199,999...	8	16	7	10	18	30	10	18	19	9	5	2
200,000 to 499,999...	18	10	35	16	53	42	65	60	25	18	14	7
500,000 to 999,999...	14	15	47	38	6	6	20	15	12	18	13	20
1,000,000 and over...		5		25					19	19	66	68
Total[1/].....	100	100	100	100	100	100	100	100	100	100	100	100

1/ Data may not add to totals shown because of independent rounding.
2/ Less than one-half of a percent.

Source: Compiled from records of the U.S. Bureau of Mines.

Stone

Most of Area 1 stone producers were in the lower two size classes in year one. Twenty-seven percent were in the less than 25,000 tons class, and 33 percent in the 25,000 to 99,999 tons class. In year two, the largest number of operations fell in the 25,000 to 99,999 tons class but less were in the less than 25,000 tons class, and one producer increased its annual production to enable it to be classed in the 1,000,000 tons category. The greatest portion of the annual output was by the operations in the 500,000 to 999,999 tons class. The difference between year one and two was 25 percent of the output being reported by an operation in the 1,000,000 tons and over class in year two with a slight drop in the percentage of annual output represented by the 500,000 to 999,000 tons class and the 200,000 to 499,999 tons class representing over half as less than in year one.

Area 2's stone industry was dominated by the 200,000 to 499,999 tons class in both percentage of number of operations and percentage of total area output. The percentage of number of operations ranged from 53 to 42 percent accounting for 65 to 60 percent of the output in year one and year two, respectively. From the number of operations standpoint, the 100,000 to 199,999 tons class ranked second percentagewise. This class ranked second in percent of output in year two but it was out-ranked by the 500,000 to 999,999 tons class in year one by 10 percent.

The stone industry in Area 3 is clustered in number of operations percentagewise in four classes. In year one, the largest percentage was in the 200,000 to 499,999 tons class followed by the 1,000,000 tons and over and the 100,000 to 199,999 tons classes. The 25,000 to 99,999 tons class in year two represented the largest percentage (30) followed by the 1,000,000 tons and over class (19 percent) and 200,000 to 499,999 tons and 500,000 to 999,999 tons

classes, representing 18 percent each. The 1,000,000 tons and over class produced the greatest amount of stone with 66 and 68 percent of the area's output in the two years. The 200,000 to 499,999 tons class ranked second percentagewise for output in year one and the 500,000 to 999,999 tons class ranked second in the later year.

Prices

The price structure for mineral aggregates in the study areas has increased at a relatively stable rate over a 12-year period. Price for these purposes means f.o.b. value of sand and gravel or stone at the first point of sales or self-use. The value does not reflect any costs needed to transport material direct to the consumer from the plant, stockpile yard or deposit. It does, however, reflect those transportation costs needed to haul the material to a processing plant.

In most years, the average f.o.b. price for crushed stone has exceeded the price for sand and gravel (table 4). The price for stone in Area 1 for the six years that stone prices exceeded prices for sand and gravel, the difference ranged from a low of 8 cents per ton in 1970 to 35 cents in 1977. For the five years (1972-1976) that prices for sand and gravel were greater than those for stone in Area 1, the price differential ranged from a low of 1 cent in 1975 to 20 cents in 1976. Prices for stone in both Area 2 and 3 annually have exceeded the prices for sand and gravel. The price differential in Area 2 ranged from a low of 47 cents in 1972 to a high of $1.09 in 1974. The price differential in Area 3 has ranged from a low of 3 cents in 1975 to a high of 36 cents in both 1969 and 1973. The fluctuation in the average price is largely the result of variation in construction activity and uses from year to year.

TABLE 4

Average Price Received Per Ton of Sand and Gravel and Crushed Stone by Area, 1966-1977

Year	Area 1			Area 2			Area 3		
	Sand and gravel	Stone	Total	Sand and gravel	Stone	Total	Sand and gravel	Stone	Total
1966	$1.65	$1.75	$1.70	$1.06	$1.67	$1.24	$0.70	$1.06	$1.05
1967	1.72	1.81	1.77	1.08	1.90	1.34	.96	1.04	1.05
1968	1.80	1.80	1.80	1.24	1.94	1.47	.91	1.15	1.14
1969	1.70	1.97	1.82	1.32	1.98	1.56	.95	1.31	1.28
1970	1.97	2.05	2.01	1.36	2.08	1.62	1.09	1.40	1.34
1971	1.87	2.07	1.95	1.47	2.42	1.80	1.31	1.47	1.44
1972	2.22	2.19	1.95	1.59	2.06	1.77	1.09	1.37	1.35
1973	2.33	2.30	2.31	1.51	2.22	1.77	1.22	1.58	1.54
1974	2.55	2.36	2.49	1.51	2.60	1.91	1.57	1.70	1.68
1975	2.95	2.94	2.95	1.82	2.76	2.16	1.61	1.64	1.64
1976	3.19	2.99	3.10	1.93	2.98	2.30	1.59	1.65	1.65
1977	2.98	3.33	3.14	2.18	3.20	2.55	1.62	1.88	1.85

Source: Compiled from records of the U.S. Bureau of Mines and data obtained from individual producers.

An assumption that might be drawn, based on standard locational theory, is that the average price per ton received for a marketable product would be relatively similar for neighboring operations and related to scale of operations. For each of the active sites, the distance to the nearest operation mining the same mineral (sand and gravel or stone) and the average distances to the three nearest competing neighbor mines were measured. These distances were used as an independent variable and average f.o.b. price as the dependent variable to determine the degree of association between them. The data are shown in figures 5 through 10 with a regression line ("best-fit" line) fitted to a set of data. The significance of the relationship between distance to nearest neighbor and price was tested through a one-way analysis of variance. The statistics derived through this analysis are given in table 5.

Mineral aggregates produced at sites immediately adjacent to one another do vary in average price on a per ton basis and proximity has little bearing on the price received. The coefficient of correlation, R, was very low for sand and gravel operations in Area 1 (.06) and Area 2 (.09) and stone in Area 2 (.02) and Area 3 (.03). The best correlation for individual commodities (sand and gravel or stone) was stone in Area 1 (.52) and sand and gravel in Area 3 (.49). These statistics indicate weak correlation between prices received by neighboring operations for sand and gravel in Area 1 and Area 2 and stone in Area 2 and 3. However, there appears to be a stronger relationship for prices versus proximity for stone operations in Area 1 and sand and gravel operations in Area 3.

Taking all aggregate operations within an area into consideration regardless of whether sand and gravel or stone, Area 3 had the stronger correlation with a statistic of .29. The correlation for each of the other two areas was very low.

TABLE 5

Analysis of Variance for Regression of Average Price F.O.B. Mineral Site on Distance to Nearest Producing Site

	Regression (between groups)			Residual (within groups)			F-ratio (calculated)	F-ratio 5 percent	Coeffic. of correlation
	Sum of squares	Degree of freed.	Mean squares	Sum of squares	Degree of freed.	Mean squares			
Area 1:									
Sand-Gravel	.0714	1	.0714	17.6220	22	.8010	.0891	4.3009	.06
Stone	4.0963	1	4.0963	10.9260	20	.5463	7.4984	4.3513	.52
Total	.0307	1	.0307	39.8116	44	.9048	.0339	4.0681	.03
Area 2:									
Sand-Gravel	.3038	1	.3038	36.4059	77	.4728	.6427	3.9782	.09
Stone	.0023	1	.0023	9.2993	19	.4894	.0048	4.3808	.02
Total	1.2983	1	1.2983	57.9005	98	.5908	2.1974	3.9498	.15
Area 3:									
Sand-Gravel	1.2385	1	1.2385	3.9729	4	.9932	1.2469	7.7086	.49
Stone	.0068	1	.0068	5.7793	36	.1605	.0424	4.1192	.03
Total	.9210	1	.9210	10.2277	42	.2435	3.7819	4.0764	.29

Using the F statistic (ratio of between sample variance and within sample variance), the calculated F statistic is less than the critical values at the 95 percent confidence level for all commodity comparisons except stone in Area 1. Thus, the null hypothesis is acceptable in all cases but one. Also, an F statistic less than 1.0 is not considered significant statistically which is applicable to those for Area 1 sand and gravel and sand and gravel - stone combination, Area 2 sand and gravel and stone and Area 3 stone.

Regression analysis of average price f.o.b. mineral site versus scale of operation reveals a very low correlation for stone operations in both Area 1 and Area 3 (table 6). Sand and gravel operations in all three areas have a relatively higher correlation. Stone operations in Area 2 had the highest coefficient of correlation (.44). However, the Area 2 stone statistics, as well as, all the others are low compared with levels normally acceptable as good indicators of correlation.

The calculated F statistics for average price versus scale of production is less than the tabled critical values for sand and gravel and stone producers in both Area 1 and Area 3. The calculated value is greater than the tabled value for both sand and gravel and stone in Area 2. Based on these statistics, there appears to be some relationship between scale and average price only in Area 2.

Scale economics do not necessarily result in lower prices per ton for sand and gravel and stone operations. Nor are variations in average price received influenced significantly by proximity to nearest neighboring producing sites. This conclusion has been reached by examining the scatter diagrams (figures 5 through 10) and the statistics calculated by the analysis of variance (tables 5 and 6).

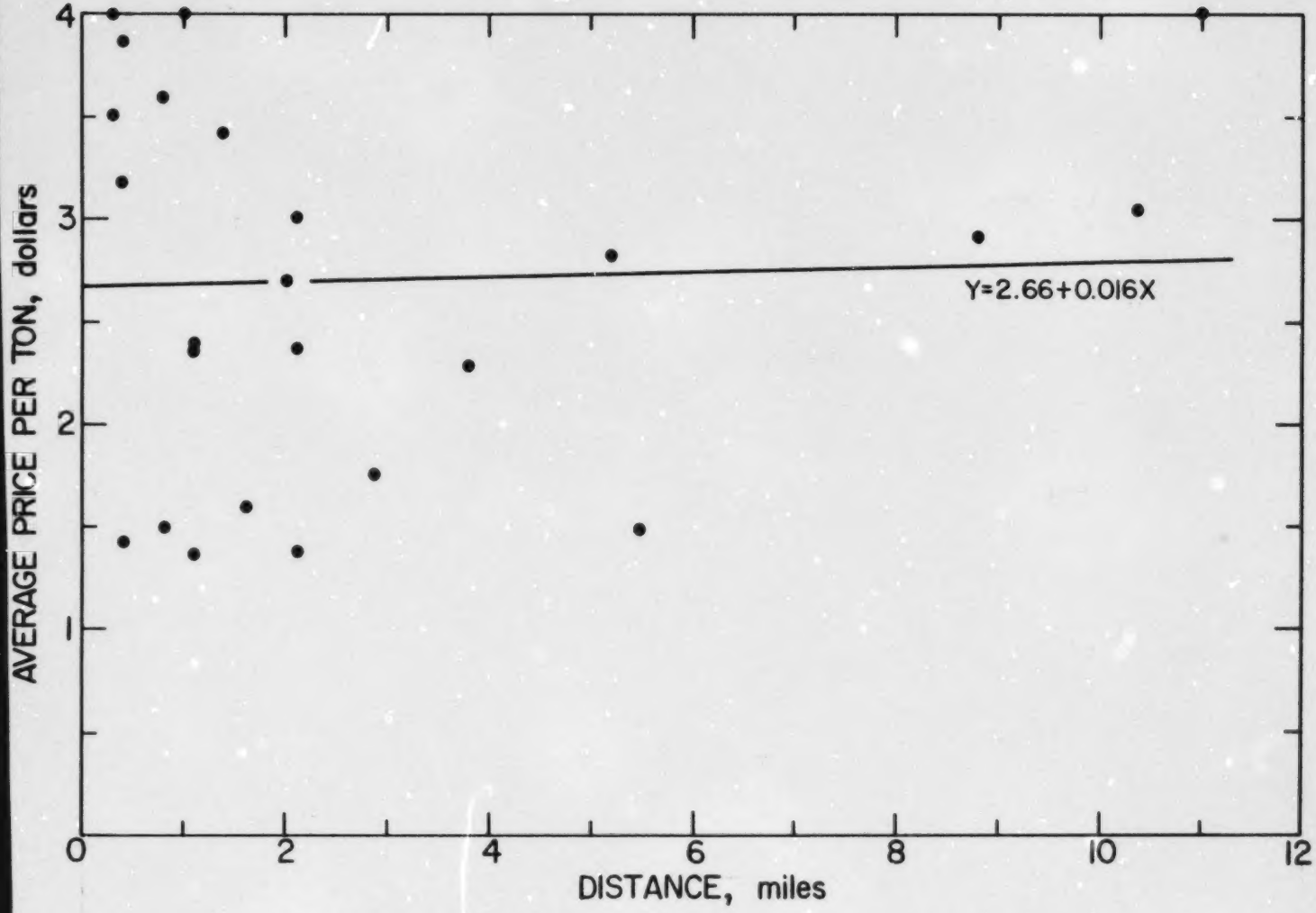

FIGURE 5. - Average price for sand and gravel and proximity to nearest neighboring producing site, Area 1.

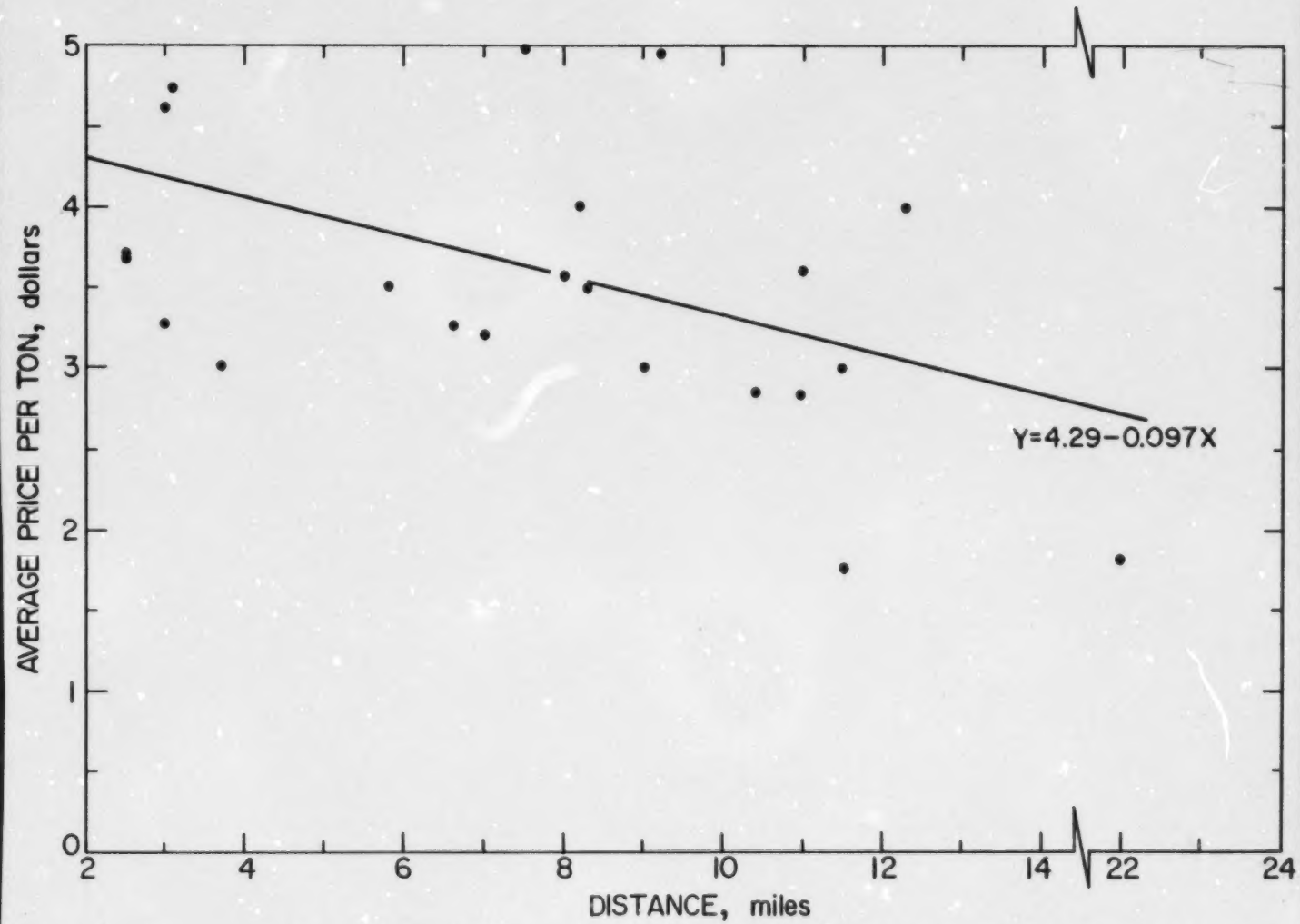

FIGURE 6. - Average price for stone and proximity to nearest neighboring producing site, Area 1.

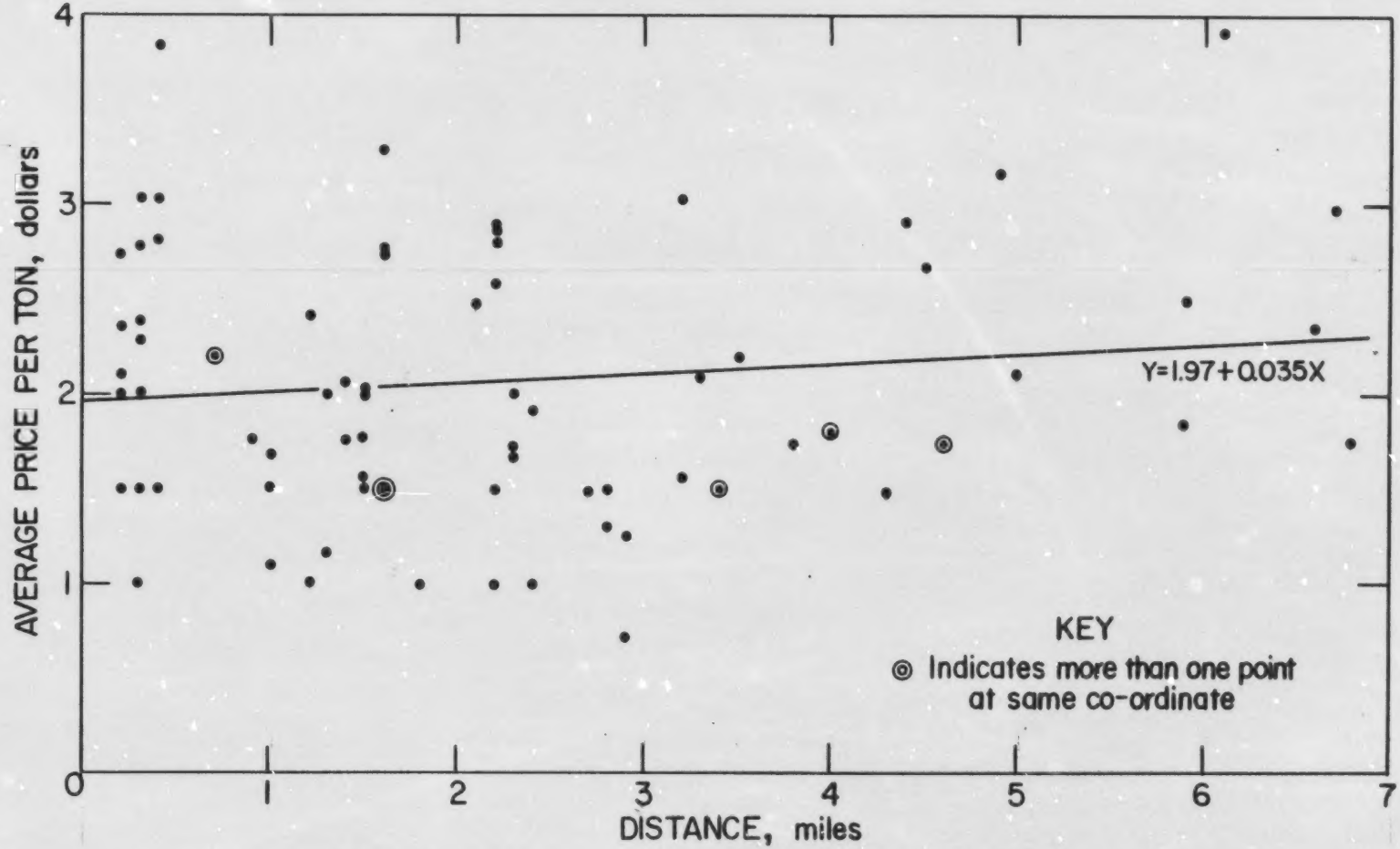

FIGURE 7. - Average price for sand and gravel and proximity to nearest neighboring producing site, Area 2.

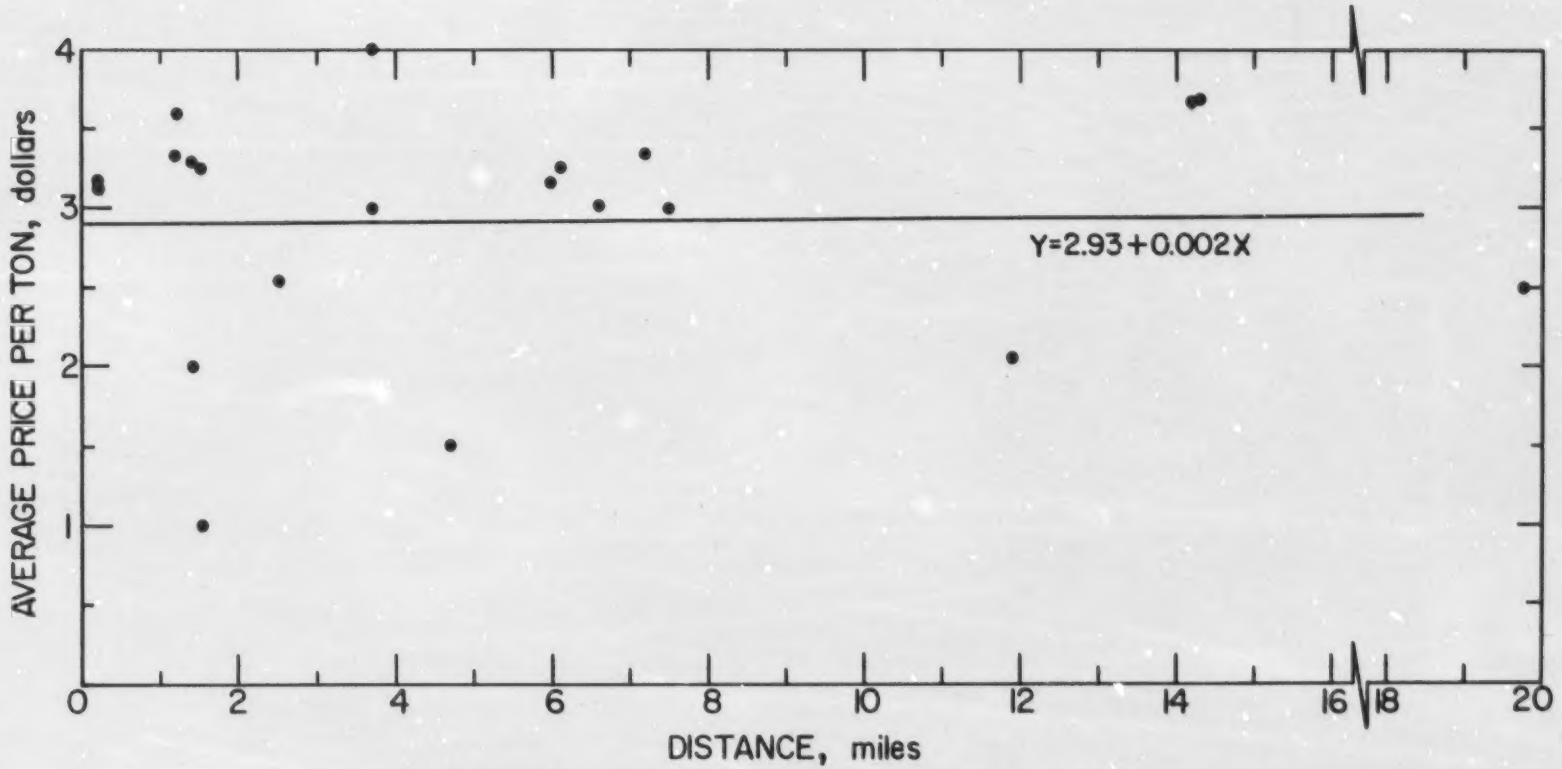

FIGURE 8. - Average price for stone and proximity to nearest neighboring producing site, Area 2.

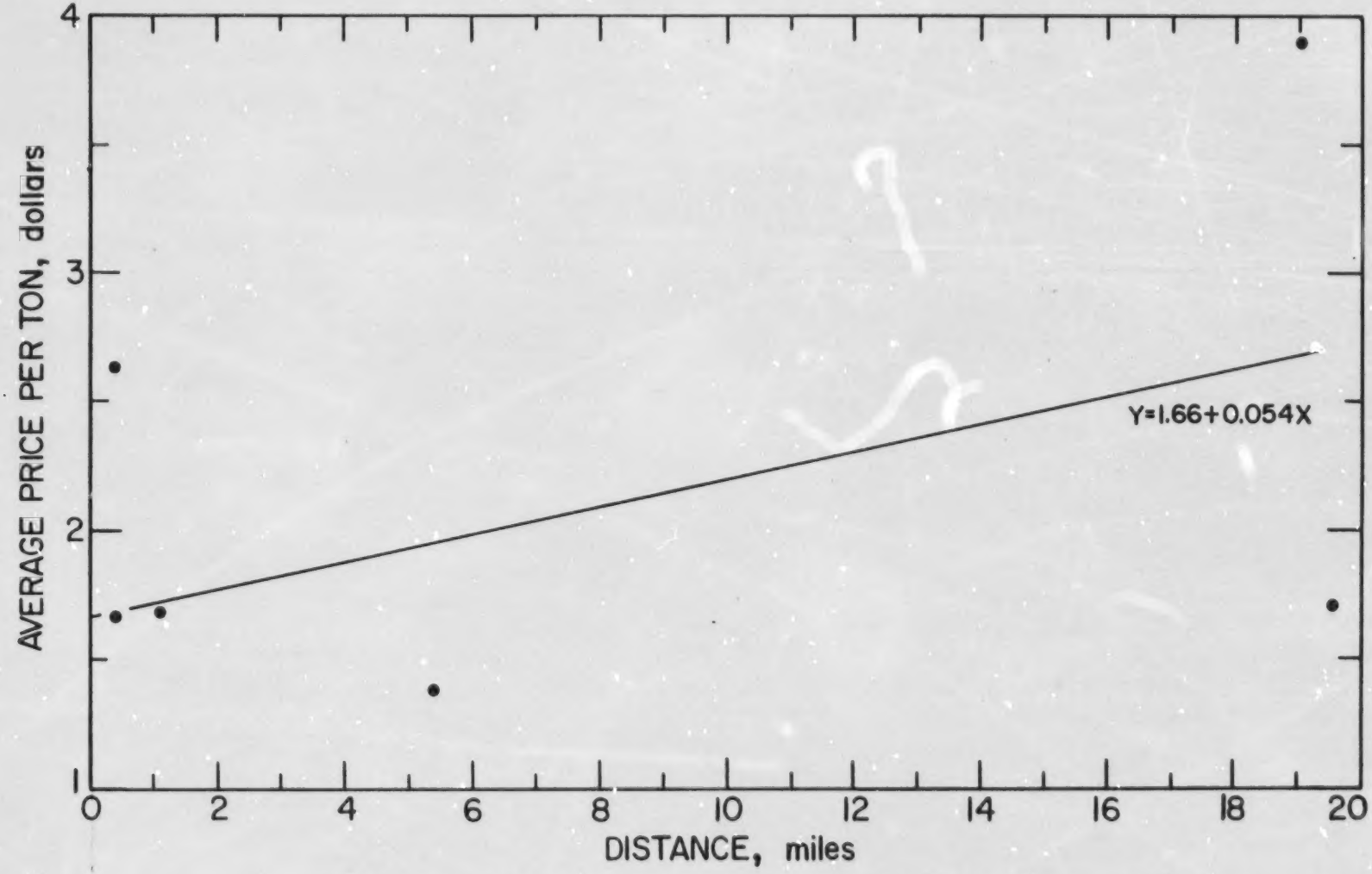

FIGURE 9. - Average price for sand and gravel and proximity to nearest neighboring producing site, Area 3.

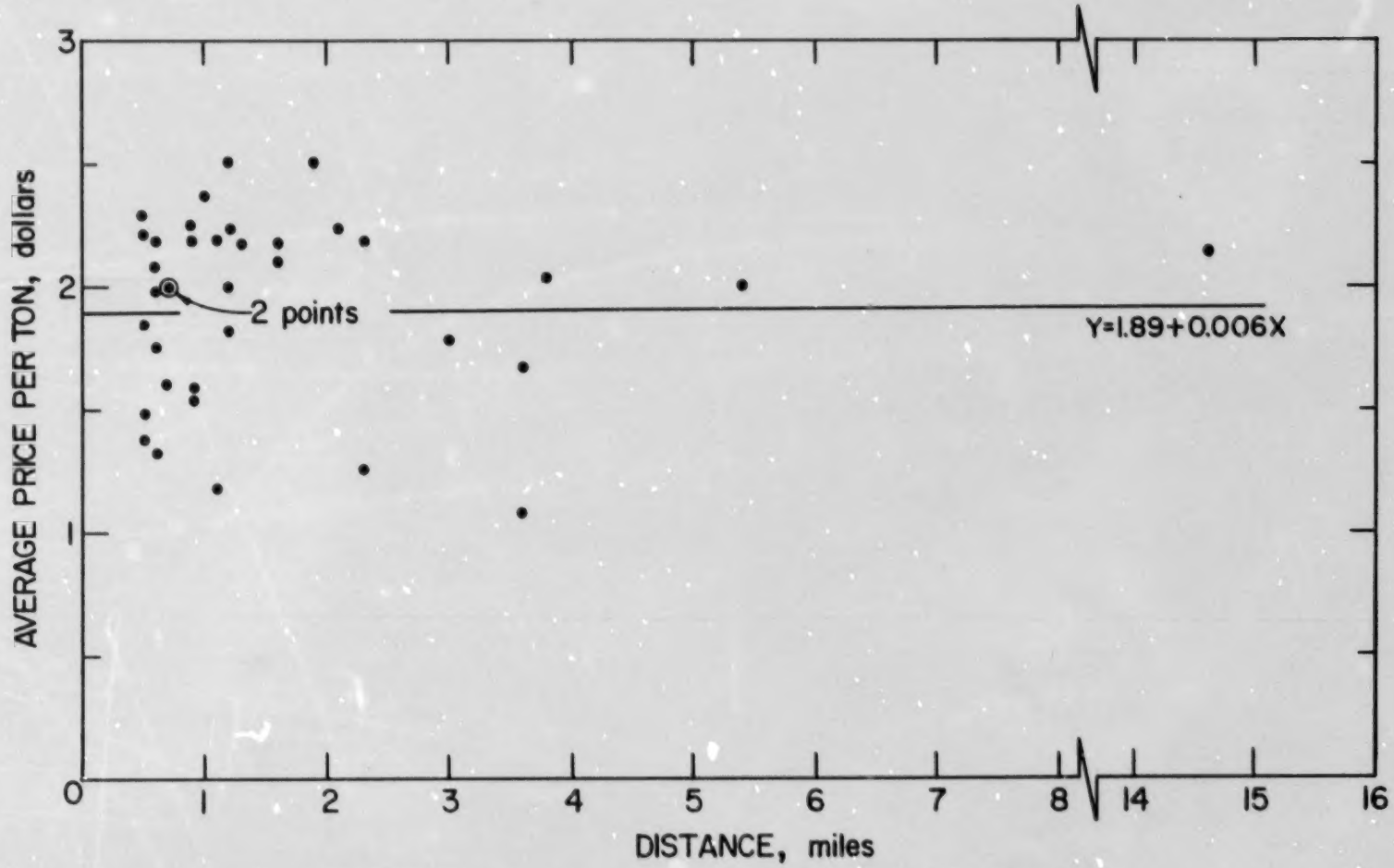

FIGURE 10. - Average price for stone and proximity to nearest neighboring producing site, Area 3.

TABLE 6

Analysis of Variance for Regression of Average Price F.O.B. Mineral Site on Size of Operation

	Regression (between groups)			Residual (within groups)			F-ratio (calculated)	F-ratio 5 percent	Coeffic. of correlation
	Sum of squares	Degree of freed.	Mean squares	Sum of squares	Degree of freed.	Mean squares			
Area 1:									
Sand-Gravel	1.1979	1	1.1979	16.4956	22	.7498	1.5976	4.3009	.26
Stone	.1449	1	.1449	14.8774	20	.7439	.1948	4.3513	.10
Area 2:									
Sand-Gravel	2.4818	1	2.4818	34.2733	77	.4451	5.5756	3.9782	.26
Stone	1.8199	1	1.8199	7.4817	19	.3938	4.6218	4.3808	.44
Area 3:									
Sand-Gravel	.7263	1	.7263	4.4851	4	1.1213	.6477	7.7086	.37
Stone	.0049	1	.0049	5.7813	36	.1606	.0304	4.1192	.03

Social Conflicts

Social conflicts or problems relating to mining mineral aggregates are many and varied. Major conflicts include visual impact to the landscape, dust, noise, ground vibrations, and vehicle traffic. To the operator, the conflicts may mean added expense to correct them or having to terminate operations. To adjacent land users, the conflicts may be annoying or be safety hazards. Comments by operators and adjacent land users in the study areas indicate an implied relationship between the location of a mineral producing site in relation to other urban land using activities and the number of complaints voiced. A social conflict is greatest with adjoining land users but may extend up to several miles from the production site. In an urban surrounding, the major complaints for the three study areas were reported to be visual appearance of the mining property, dust, noise, traffic and vibration, in decreasing order. Complaints in rural areas were primarily with regard to visual appearance, dust, and traffic. Most of the complaints, reported by mineral operators who indicated receiving complaints, came from individuals residing within one-fourth to one mile of the mine and/or processing plant. The information obtained indicates that the intensity of the conflicts decreases as distance from the mine site increases.

Conflicts over land use are inevitable when mining operations have to be located at the urban-rural interface. The growing cities need not only the construction materials, but also the land near which they are mined. Land use conflicts usually result in either complete prohibition or restrictive measures imposed on operators. Either result increases the cost of operation, but usually restrictive measures are less costly than relocation to more distant sites.

External costs are costs imposed on society by production activity, and are characterized in many cases as being rather intangible in terms of trying to

assign a monetary value to them. Because of this fact, the absolute measurement of total social costs created by a mining operation in the urban environment is difficult, if not impossible. One way to determine a value is to estimate the cost to the producer to ameliorate the social conflicts (impact to landscape, dust, noise, vibrations, and truck traffic). Taking into consideration relative location of production sites and estimated costs to ameliorate social conflicts, a conflict severity index can be estimated for two categories of producers: Those producers located within predominately urban zones, and those located in a transitional and/or rural zones. A theoretical conflict severity index for urban zones can be expressed as a linear regression formulation, $Y = 30.05 + 10.61X$ and for transitional - rural zones as $Y = 17.12 - 0.96X$ (Ralston, 1975, p. 80).

A cost function can be expressed in terms of the total costs of producing mineral aggregates at site i and serving market j. The total cost function can be expressed as:

$$TC_{i,j} = P_i + T_{i,j} + CS_i$$

where $TC_{i,j}$ is total costs

P_i is production costs

$T_{i,j}$ is transportation costs

CS_i is conflict severity costs

The production costs represent the costs incurred in producing the mineral aggregate. These costs include labor, operating supplies, administration overhead, depreciation, depletion, taxes, insurances, reclamation expense, and a profit margin. They generally are expressed in terms of cost and/or price f.o.b. mine. The transportation costs are the average truck transportation costs for haulage of the mineral aggregate from the production site to the consuming site. The conflict severity cost for this study was derived directly from the conflict severity index. Some of these costs may be included in the production costs but

the major portion are related externally to the actual production of the aggregate.

Ten active mineral aggregate sites were selected for each area in this study as an example to illustrate the social cost function. The sites were selected from different sectors of each area with varying annual productions and distances from the CBD (Central Business District).

Data for the selected sites were calculated and resulted in a statistic expressed in cents per ton. If modifications were implemented in the production and haulage systems to ameliorate actual or potential conflicts, the social costs may approach those shown in table 7. It should be recognized these statistics are hypothetical, do not represent actual costs and may in some instances not be realistic. However, the data do illustrate a potential escalation in costs to the consumer for materials supplied from urban zone sites versus rural sites.

Analysis of the data shows that social costs in Area 3 for sites located in an urban zone represent a greater percentage of production costs and production costs plus transportation costs than the other two areas. The percentage in Area 3 ranges from a low of 35 to a high of 104 of production costs for urban localities and from 19 to 71 percent of production costs plus transportation costs. Costs in rural zones for each of the three areas represent only a small percentage of production costs and production costs plus transportation costs.

TABLE 7

Conflict-Production Cost Index for
Selected Mineral Aggregate Sites

Site	Density zone	Conflict severity, dollars per ton	Percent of production costs	Percent of production plus transportation costs
Area 1:				
1	urban	$1.89	104	56
2	rural	.06	2	1
3	rural	.12	5	2
4	rural	.30	8	3
5	rural	.12	8	3
6	urban	1.05	37	20
7	rural	.15	7	2
8	rural	.06	2	1
9	rural	.04	1	1
10	urban	1.78	50	30
Area 2:				
1	urban	1.35	31	26
2	urban	1.33	37	29
3	rural	.28	9	6
4	rural	.30	9	6
5	rural	.32	10	6
6	urban	1.15	38	27
7	rural	.13	5	3
8	urban	1.00	31	22
9	rural	.08	3	1
10	urban	.88	59	30
Area 3:				
1	rural	.16	9	5
2	rural	.61	41	27
3	urban	1.31	89	58
4	urban	1.56	104	71
5	urban	1.18	79	45
6	urban	.62	35	19
7	rural	.10	6	3
8	urban	.73	46	25
9	urban	1.15	72	42
10	rural	.01	1	1

MINERAL RESOURCE ZONES

Land use is an important element affecting the quality of our physical environment. The mineral aggregate industry is a user of land and by its very nature, directly affects the landscape. However, the land used for the extraction of sand and gravel and stone is usually a small portion of the total land in an urban area.

Approximately 3.3 percent (103,232 acres) of the land in Area 1 is occupied by either presently active mining operations or abandoned mines. About 32 percent of the mined area is in Butler County. No distinction is made between active or abandoned mined land nor are the areas identified as to mineral commodity, such as bituminous coal, sand and gravel, stone, or clay. Most of the land identified as mining is large tracts of land mined for bituminous coal and not reclaimed.

Mining occupies a very small percentage of the land in Area 2. Of this land use, 96 percent has been classified as land used for the extraction of sand and gravel. The remaining four percent is land used for the extraction of stone and minerals other than sand and gravel. No distinction is made between active quarries or pits and areas mined previously and now abandoned. A large portion of the 12,485 acres denoted as mining are areas not currently being mined. Many of these areas were quarries and pits used to supply aggregate for the highway expansion programs of the sixties.

Mining occupies a small portion of land in Area 3. About 0.4 percent (13,000 acres) of the land is classified as mining operations.

Constraints confronting existing mines are (1) encroachment by other land uses, (2) stricter environmental regulations than existed when mining was originally begun, (3) permit renewal, and (4) public involvement. The latter, which arises from concern about noise, dust, appearance, traffic flow and

TABLE 8

Land Use by County, Area 1, 1975
(percent)

Land Use	Allegheny	Armstrong	Beaver	Butler	Lawrence	Washington	Westmoreland	Total Area
Forest.....	23.7	40.6	37.4	32.2	21.4	21.4	38.2	31.9
Agriculture or open space.....	32.9	49.5	38.1	50.0	58.8	62.6	43.0	47.7
Urban:								
Residential....	35.7	4.7	16.9	9.3	9.6	12.0	13.3	14.7
Industrial.....	2.8	.1	1.4	.4	.6	.3	.6	.9
Commercial.....	.9	1/	.3	.2	.4	.1	.3	.3
Institutional..	1.0	1/	.2	.2	.5	.2	.3	.3
Mining.....	.7	4.8	1.9	6.5	6.3	3.2	1.3	3.3
Military.....	.1	-	-	-	-	-	1/	.1
Recreational.....	2.3	.3	3.4	1.2	2.4	.2	3.1	1.7
Total 2/.....	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

1/ Less than .05 percent.
2/ Percentages may not add to 100 because of independent rounding.

Source: Compiled from data obtained from Green International, Inc.

TABLE 9

Land Use by County, Area 2, 1971
(percent)

Land Use	Essex	Middlesex	Norfolk	Plymouth	Suffolk	Total Area
Forest	46.4	51.8	52.0	60.5	6.4	52.0
Agriculture or open space	12.3	10.9	9.6	11.3	3.3	10.9
Wet land	14.0	6.1	5.5	9.6	8.0	8.6
Urban:						
Residential	18.5	21.3	23.6	13.1	40.6	19.3
Industrial	1.1	1.6	1.5	.4	4.3	1.2
Commercial	1.2	1.6	1.2	.8	10.2	1.4
Other	3.5	4.3	3.5	2.2	20.0	3.8
Mining:						
Sand and gravel	.6	.7	1.1	.7	.2	.7
Other[1/]	.1	[2/]	[2/]	-	.1	[2/]
Waste disposal area[3/]	.2	.2	.2	.1	.6	.2
Recreational	2.1	1.5	1.8	1.2	6.2	1.7
Total[4/]	100.0	100.0	100.0	100.0	100.0	100.0

1/ Extraction of stone and materials other than sand and gravel.
2/ Less than .05 percent
3/ Land used for dumping waste and refuse materials such as sanitary land fills; automobile dumps; and filter beds.
4/ Percentages may not add to 100 because of independent rounding.

Source: MacConnel, et al. (1973 and 1974).

TABLE 10

Land Use by County, Area 3
(percent)

Land Use	Broward	Dade	Palm Beach
Forest	69.1[1/]	83.6[2/]	59.1[3/]
Agriculture and open space	18.3	4.8	36.5
Urban:			
Residential	9.8	7.8	1.8
Industrial	.6	.6	.1
Commercial	.9	.6	.2
Institutional	.5	.7	.3
Other	.4	.7	1.4
Mining	.4	.2	.1
Recreational	-	1.0	.5

1/ Principally Conservation Area.
2/ Everglades National Park - 32 percent; Conservation Area - 18 percent.
3/ Conservation Area - 31 percent; lakes - 16 percent.

Source: Compiled from data obtained from County Planning Departments and the Florida Bureau of Coastal Zone Planning.

blasting vibrations, is usually brought about by encroachment from new residential developments.

For new mines, major constraints are (1) obtaining land of sufficient size with quality material by purchase or lease, (2) applying for and obtaining permits on a timely basis, (3) the necissity for creating a good neighbor relationship prior to and during mining, and (4) developing a mining, preparation, and post-mining plan that will satisfy the numerous environmental regulations that warrant the capital investment.

Urban encroachment limits mineral reserves by covering potential commercial sites and hems in existing operations so that expansion is restricted. Loss of reserves not only results directly from urban encroachment but can result indirectly from stricter environmental regulations. Setbacks, noise, dust, water drainage, traffic congestion, and highway deterioration head the list of items associated with mining as nuisance problems.

Traditionally, governmental bodies have used controls, such as zoning ordinances and building codes, as a tool to implement their decisions on the use of land. These controls usually take the form of regulations which are intended largely to prohibit a use of land which is not "in the public interest." Existing zoning regulations often are directed to discouraging mining.

Mining, as defined by various township ordinances of Area 1, covers coal, limestone, sandstone, sand, gravel, clay, natural gas, and other minerals and is referred to as strip mining, surface mining, mineral extraction, mineral removal, quarrying and/or deep mining. Ordinances and bylaws restricting the use of land for the excavation of minerals are principally controlled by the township supervisors or commissioners in accordance with provisions of Sections 603 and 609 of the Pennsylvania Municipalities Planning Code, Act 247 of 1968,

as amended. Reference is often made to the requirements of appropriate State mining and reclamation regulations.

Twenty-one of the townships where mining occurs or are adjacent to townships with mining reported having adopted some form of regulation related to mining (table 11). These regulations stipulate one or more of the following controls: (1) method of removal, (2) hours of operations, (3) area or depth of mining, (4) setback and/or slope control, (5) screening and/or fencing, (6) drainage and erosion control, (7) water pollution, (8) ground control, (9) reestablishment of ground levels and grades, (10) disposition of topsoil, and (11) revegetation.

The mining of sand, gravel, and stone in Area 2 is controlled at the government level primarily through town zoning ordinances and bylaws under the heading of "earth removal." The ordinances and bylaws which regulate the extraction of sand, gravel, and stone also generally cover the removal of sod, topsoil, loam, clay, rock, peat and humus. "Earth removal" regulations within the five counties vary from town to town. The bylaws and ordinances range from minimal statements of one paragraph to detailed regulations which specify requirements for obtaining a permit, operating regulations, and reclamation procedures.

All but 6 of the 147 towns in Area 2 have adopted some form of regulation to control mining (table 12). Of this number, 96 towns have detailed regulations which cover the (1) method of removal, (2) hours of operations, (3) haulage routes, (4) area and depth of excavation to street and property lines, (6) steepness of slopes excavated, (7) drainage and erosion control, (8) screening and/or fencing, and (9) nuisance control including dust, noise, fumes and smoke. Reclamation requirements that may be part of a town's ordinances are (1) performance bond, (2) regrading, (3) disposition of topsoil, (4) disposition of

TABLE 11

Regulations Applicable to Mining in Area 1

County and township	Performance bond	Permit	Method of removal	Hours of Operation	Area and/or depth of excavation	Setback and/or slope control	Reclamation plan	Screening and/or fencing	Drainage and erosion control	Water pollution control	Ground control	Reestablish ground levels and grade	Disposition of topsoil	Revegetation	Natural conservation site protection	Haulage routes	Haulage weight limits	Repair damaged roads
Allegheny:																		
Collier	X	X			X	X	X		X			X	X			X		
North Fayette	X	X			X	X						X		X		X	X	X
Robinson																	X	
South Fayette	X																X	X
Armstrong:																		
Gilpin								X	X	X					X			
South Buffalo						X		X	X	X								
Beaver:																		
Hanover	X				X	X	X										X	X
New Sewickley					X	X	X											
Butler:																		
Marcer	X																X	X
Lawrence:																		
Hickory	X	X			X	X		X	X		X	X	X	X				
Mahoning					X	X	X		X	X	X	X	X	X		X	X	
Neshannock	X											X		X			X	
North Beaver		X				X	X					X	X				X	
Pulaski	X	X			X	X	X					X	X	X			X	
Shenango	X	X	X			X			X	X	X	X	X	X		X	X	X
Wilmington	X	X			X	X		X	X			X		X				
Westmoreland:																		
Franklin	X	X	X		X	X	X	X	X					X				X
Ligonier	X	X	X	X	X			X	X				X	X			X	X
North Huntingdon	X																X	X
Penn	X	X	X	X	X	X		X									X	X
Rostraver	X				X	X	X					X	X				X	X

Source: Township Zoning Ordinances.

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TABLE 12

Regulations Applicable to Mining and/or Earth Removal in Area 2

County	Number of towns	With regulations	Mining and/or earth removal prohibited	Reclamation not indicated in regulations
Essex.....	34	34	2	13
Middlesex.....	54	51	2	25
Norfolk.....	28	28	3	5
Plymouth.....	27	25	0	11
Suffolk.....	4	3	0	1
Total....	147	141	7	55

Source: Town Regulations.

stumps and boulders, (5) planting of suitable cover, and (6) repair of damaged roads.

The three counties in Area 3 of southeastern Florida have enacted mining or earth mining ordinances.

Dade County regulates the excavation of stone and sand using the zoning regulations titled Lake Excavations. The major standards of the regulations relate to backfilling, degree of stope, posting and staking of the property, fencing, use of explosives, hours of operations, setbacks, and reclamation (table 13). Sections of the excavation regulations for Broward and Palm Beach Counties cover many of the same items.

One technique which could be utilized to minimize conflicts and insure continuity in supply would be the establishment of mineral resource extraction districts. The concept is a locational control which allows surface mining operations as permitted uses within a specified zoning district. The mineral district or zone would be established as a reservation zone to prevent land uses from encroaching upon mineral lands prior to extraction. In addition, the end use of the mineral lands would be systematically planned prior to mining.

The concept of establishing mineral resource zones has been proposed in some areas and, in selected instances, implemented. Colorado and Wisconsin are cited here as examples.

As part of the statute concerning the reclamation of land affected by mining, the Colorado legislature has provided for the preservation of commercial mineral deposits (Colorado, 1973, pp. 10-11). After July 1, 1973, no governing body of any city, town or county could by zoning, rezoning or granting a variance permit the use of an area known to contain a commercial mineral deposit in a manner which would interfere with present or future mineral extraction. Such governing bodies under section 92-36-4 of the Act are required to conduct a

TABLE 13

Regulations Applicable to Excavation of Stone and Sand, Area 3

	Broward County	Dade County
Performance bond	X	X
Permit	X	X
Liability insurance	X	
Hours of operation	X	X
Use of dynamite	X	X
Area and/or depth of excavation	X	X
Setback and/or slope control	X	X
Stacking and/or fencing	X	X
Control grading	X	X
Disposition of excavated material and/or topsoil		X
Rehabilitation and/or filling excavation	X	X
Road dust control	X	
Repair and restoration of roads		X
Removal of structures, stockpiles, etc. after operation abandoned	X	

Source: County regulations.

study of commercial mineral deposits within their jurisdictions and develop master plans for the extraction of such deposits. In developing a plan, the following factors must be considered:

(1) Any system adopted by the Colorado Geological Survey grading commercial mineral deposits according to such factors as magnitude of the deposit and time of availability for and feasibility of extraction of a deposit;

(2) The potential for effective multiple-sequential use which would result in the optimum benefit to the landowner, neighboring residents, and the community as a whole;

(3) The development or preservation of land to enhance development of physically attractive surroundings compatible with the surrounding area;

(4) The quality of life of the residents in and around areas which contain commercial mineral deposits;

(5) Other master plans of the county, city, or town;

(6) Maximization of extraction of commercial mineral deposits; and

(7) The ability to reclaim the mined area.

The Wisconsin Legislature, in recognition of the importance not only of a continuing and reliable supply of minerals but of the need for environmental protection, in 1973 enacted Chapter 318. The Statute provides for regulation of prospecting and mining, and for creation of a mine reclamation council. It also directs that a comprehensive state program of mineral resources zoning and financial incentives be submitted to the legislature for the purpose of discouraging those uses of lands which tend to preclude the mining of minerals lying beneath. A model zoning ordinance was proposed that covers both the substantive and procedural problems involved with zoning for mineral reservation

and management. The model ordinance proposes to accomplish three general purposes, using the umbrella of a zoning ordinance (Preston, 1974, pp. 1-2). The first objective is to protect mineral deposits so that they can later be mined to provide for the future economic development of the county. The second purpose is to regulate mining and mining activity to prevent nuisance situations and to protect the public health, safety, and general welfare of the citizens of the county. The final purpose is to govern the sequential or postmining use of land for the purpose of compatibility with general land-use plans. Mining is meant to include both metallic and nonmetallic mineral extraction and mineral extraction is considered a temporary use of land.

The model ordinance has two methods to provide for the protection of mineral deposits. The first method involves the creation of mineral reservation districts. Some of the principal objectives are identifying the location of present and future mining areas and the availability of mineral-bearing lands, use of the land for development and reclamation, and the maximization of the short- and long-term benefits of mining (Preston, 1974, pp. 5-6). Two types of land use are permitted in the district: agricultural and forestry, and three types of special exception uses. The first type of special exception in a mineral reservation district is non-structural conservancy uses such as those permitted in shoreland zoning ordinances. The next is a nonmining special exception which consists of any permitted use or special exception in an adjacent district. Lastly, mining is considered a special exception.

The second alternative for regulating mineral extraction provides for creation of a special exception for mining in an agricultural, forestry, or conservancy zone. This special exception is to provide the ability to protect adjoining land uses from mining and to give flexibility in dealing with deposits whose location is not precisely known.

A mechanism for preserving mineral sites in a mineral resource zone as proposed by Pennington has been referred to as transfer of mineral zone development rights system (TMDR) (Pennington, 1978, p. 12). TMDR is a variation of the transfer of development rights (TDR) concept that is frequently used to preserve agriculture land by transferring development rights from designated agricultural areas to designated development district (Pennsylvania, 1977, p. C-10). TMDR, according to Pennington, "works by identifying areas for mineral resource zones, which are called transfer areas, and areas suitable for higher-intensity development (development districts). To protect the mineral resource zone, the development which previously could have occurred in the mineral resource zone is transferred to the development district. The transfer is completed by issuing development right certificates to property owners in the mineral resource zone. These development right certificates represent the loss in value to property owners resulting from restrictions placed on their land. Property owners sell the development rights to their land, thereby giving up the right to develop their land in the mineral resource zone. The system can work on a voluntary basis or be mandatory. As a voluntary system, bonuses are granted to encourage preservation of mineral resources. For a mandatory system, methods are utilized to insure compensation for restrictions placed on the land" (Pennington, 1978, p. 12). Purchase of development rights appears to be a feasible means for insuring that development does not occur over valuable mineral deposits and provides for buffer zones between proposed mining areas and existing developed areas.

Land within a mineral resource zone would have two values--a resource value which is the appraised value of the land as it exists or a development value. Five options would be available to a landowner: (1) sell both values to a land developer, (2) sell both values to a mineral oriented firm, (3) sell the

resource value to a mineral firm and development value to a developer, (4) sell only the development value and continue to farm, or (5) sell both values and lease back. In any case, the first priority for use of the land would be preservation for mineral extraction.

Using the zoning regulations for the three areas for illustrative purposes indicates that governmental agencies instigating the regulations do not give consideration to the protection of potential sites or insure that the highest quality deposits be reserved for future use. The planning process as it presently exists in these areas, as well as many others, is reactive rather than a dynamic growth management oriented mechanism. The creation of mineral resource zones by local governing bodies may be a means for reducing future conflicts resulting from mining in an urban environment and provide the greatest potential for preserving sites for extraction of mineral aggregates. The mineral aggregate producer, and indirectly the public, jointly may solve the problems of supplying mineral aggregates of usable quality and sufficient quantity at reasonable prices and at acceptable environmental costs.

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